PB88-204268

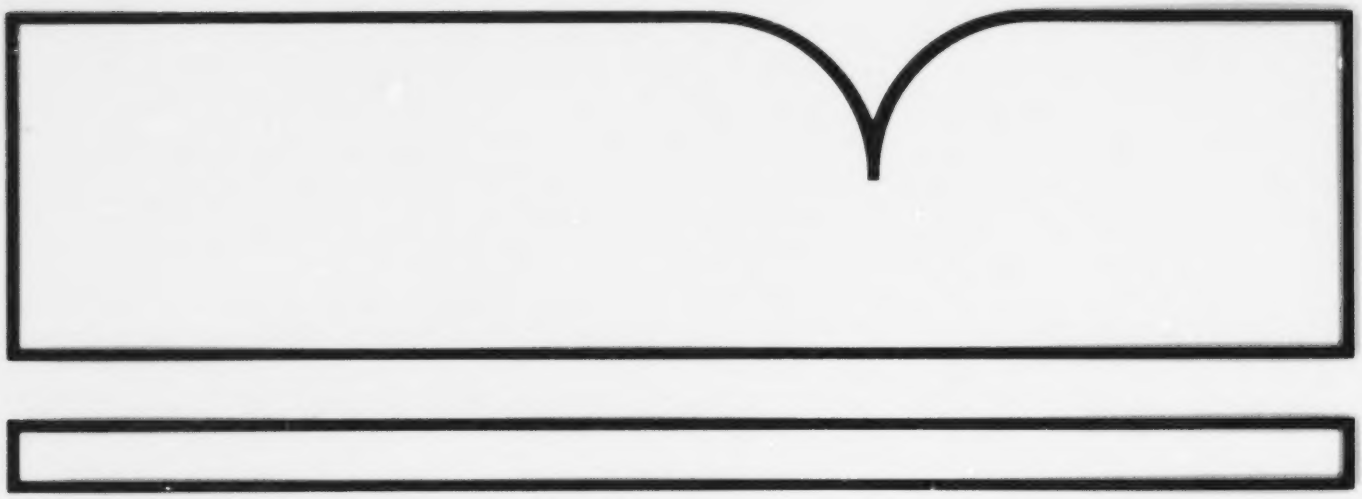
Advanced Utility Simulation Model
Multi-Period, Multi-State Module Design
Documentation (Version 1.0)

(U.S.) Carnegie-Mellon Univ., Pittsburgh, PA

Prepared for

Environmental Protection Agency
Research Triangle Park, NC

Apr 88



U.S. Department of Commerce
National Technical Information Service
NTIS

TECHNICAL REPORT DATA
(Please read Instructions on the reverse before completing)

1. REPORT NO.	2.	3. RECIPIENT'S ACCESSION NO.
EPA/600/8-88/071d		PB88 8 - 20 42 68 7AS

4. TITLE AND SUBTITLE	5. REPORT DATE
Advanced Utility Simulation Model, Multi-Period Multi-State Module Design Documentation (Version 1.0)	April 1988
	6. PERFORMING ORGANIZATION CODE
7. AUTHOR(S)	8. PERFORMING ORGANIZATION REPORT NO.
Richard Edahl, Navin Tyle, Sarosh N. Talukdar, and Nancy L. Pachavis	
9. PERFORMING ORGANIZATION NAME AND ADDRESS	10. PROGRAM ELEMENT NO.
Carnegie-Mellon University Department of Electrical and Computer Engineering Pittsburgh, Pennsylvania 15213	11. CONTRACT/GRANT NO. CR808514* and CR809461*
12. SPONSORING AGENCY NAME AND ADDRESS	13. TYPE OF REPORT AND PERIOD COVERED
EPA, Office of Research and Development **Air and Energy Engineering Research Laboratory** **Research Triangle Park, NC 27711**	Final; 10/82 - 11/84 14. SPONSORING AGENCY CODE **EPA/600/13**

15. SUPPLEMENTARY NOTES AEERL project officer is Larry G. Jones, Mail Drop 62, 919/514-7716. (*) Cooperative Agreement was with the University of Illinois at Urbana-Champaign.

16. ABSTRACT The report is one of 11 in a series describing the initial development of the Advanced Utility Simulation Model (AUSM) by the Universities Research Group on Energy (URGE) and its continued development by the Science Applications International Corporation (SAIC) research team. The AUSM is one of four stationary source emission and control cost forecasting models developed by EPA for the National Acid Precipitation Assessment Program (NAPAP). The AUSM projects air pollution emissions (SO2 and NOx), generating technology types and costs of operation, and combinations of fuels and emission control technologies to simultaneously meet electric demand and emission constraints on a least cost basis for each year through 2010. Thirteen electric demand regions are simulated, and output is provided for each of the 48 states. The initial version of AUSM, designated Version 1.0, was delivered by URGE in November 1984 and August 1985. Further development of the AUSM by SAIC between 1985 and 1988 has resulted in the development of Versions 2.0 and 3.0. Reports describing these revisions by SAIC to the initial Version 1.0 of AUSM are also part of this series.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS		b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group	
Pollution	Sulfur Dioxide	Pollution Control	13B	07B
Utilities	Nitrogen Oxides	Stationary Sources		
Emission	Fuels		14G	21D
Cost Analysis	Electrical Power Demand		14A	
Simulation				20C
Forecasting	Mathematical Models			12A

18. DISTRIBUTION STATEMENT	19. SECURITY CLASS (This Report)	21. NO. OF PAGES
Release to Public	**Unclassified**	29
	20. SECURITY CLASS (This page) **Unclassified**	22. PRICE A03 12.95

EPA Form 2220-1 (9-73)

PB88-204268

EPA/600/8-88/071d
April 1988

ADVANCED UTILITY SIMULATION MODEL, MULTI-PERIOD MULTI-STATE MODULE DESIGN DOCUMENTATION (VERSION 1.0)

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CR808514 and CR809461

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This study was conducted in cooperation with the
National Acid Precipitation Assessment Program

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RESEARCH TRIANGLE PARK, NC 27711

REPRODUCED BY
U.S. DEPARTMENT OF COMMERCE
National Technical Information Service
SPRINGFIELD, VA. 22161

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ABSTRACT

The Advanced Utility Simulation Model (AUSM) is one of four stationary source emission and control cost forecasting models developed by the Air and Energy Engineering Research Laboratory for the National Acid Precipitation Assessment Program. The AUSM model projects air pollution emissions (sulfur dioxide and nitrogen oxides), generating technology types and costs of operation, and combinations of fuels and emission control technologies to simultaneously meet electric demand and emission constraints on a least cost basis for each year through 2010. Thirteen seperate electric demand regions are simulated and output is provided for each of the 48 states.

This document is one of several in this series that describes the initial development of the AUSM model by the Universities Research Group on Energy (URGE) and its continued development by the Science Applications International Corporation (SAIC) research team. The initial version of AUSM. designated by EPA as Version 1.0, was delivered by URGE in November 1984 and August 1985. Further development of the AUSM model by the Science Applications International Corporation (SAIC) in the 1985-1988 period has resulted in the development of Versions 2.0 and 3.0. Reports describing these revisions by SAIC to the initial version 1.0 of AUSM are also part of this series.

CONTENTS

		Page
Abstract		iii
Figures		v
Acknowledgement		vi
1.	Introduction	1
	Purpose	1
	Approach	1
	Methodology	1
2.	An Overview of the Multi-Period, Multi-state Module	3
	Model Environment	3
3.	Program Design	5
	Preparatory Programs	5
	MPMS	7
4.	Data Base Design	7
	Regional Scenario File	7
	Preliminary Files	8
	Report Files	13
5.	References	15
Appendix A.	Fortran Coding Restrictions	16

FIGURES

Figure		Page
1-1	The information flows and "strong" couplings between the MPMS module and the State-level AUSM	2

ACKNOWLEDGEMENT

The AUSM development work documented by this report was carried out through cooperative agreements (CR808514 and CR809461) between the Environmental Protection Agency (EPA) and the University of Illinois at Urbana-Champaign. The agreement included subcontracts with Cornell University and Carnegie-Mellon University. The researchers performing the work were known collectively as the Universities Research Group on Energy (URGE).

The URGE researchers were led by James J. Stukel, Director, Public Policy Program, College of Engineering, University of Illinois at Urbana-Champaign. This report was authored by URGE project researchers at Carnegie-Mellon University. The report's authors are Richard Edahl, Navin Tyle, Sarosh N. Talukdar and Nancy L. Pachavis, Department of Electrical and Computer Engineering, Pittsburg, Pennsylvania 15213.

SECTION 1

INTRODUCTION

1.1. Purpose

The purpose of the National Model is to complement the state-level AUSM. In particular, the National Model calculates three critical inputs to the state-level AUSM:

- inter-state transfers of energy
- generation plant expansions aggregated to the state level
- state emission caps.

It also computes the amount of each fuel used by state and period for use in the National Coal Module.

1.2. Approach

1. Divide the nation into multi-state regions so that the energy transfers across the regional boundaries will remain small over the time-horizon-of interest. This makes regions essentially independent from the view points of generation and energy transfers.

2. Develop a multi-period multi-state (MPMS) model which can make optimal (least cost) decisions on which state to site new plants in, when to build them, what the inter-state energy transfers should be and at what levels the emission caps for each state should be set.

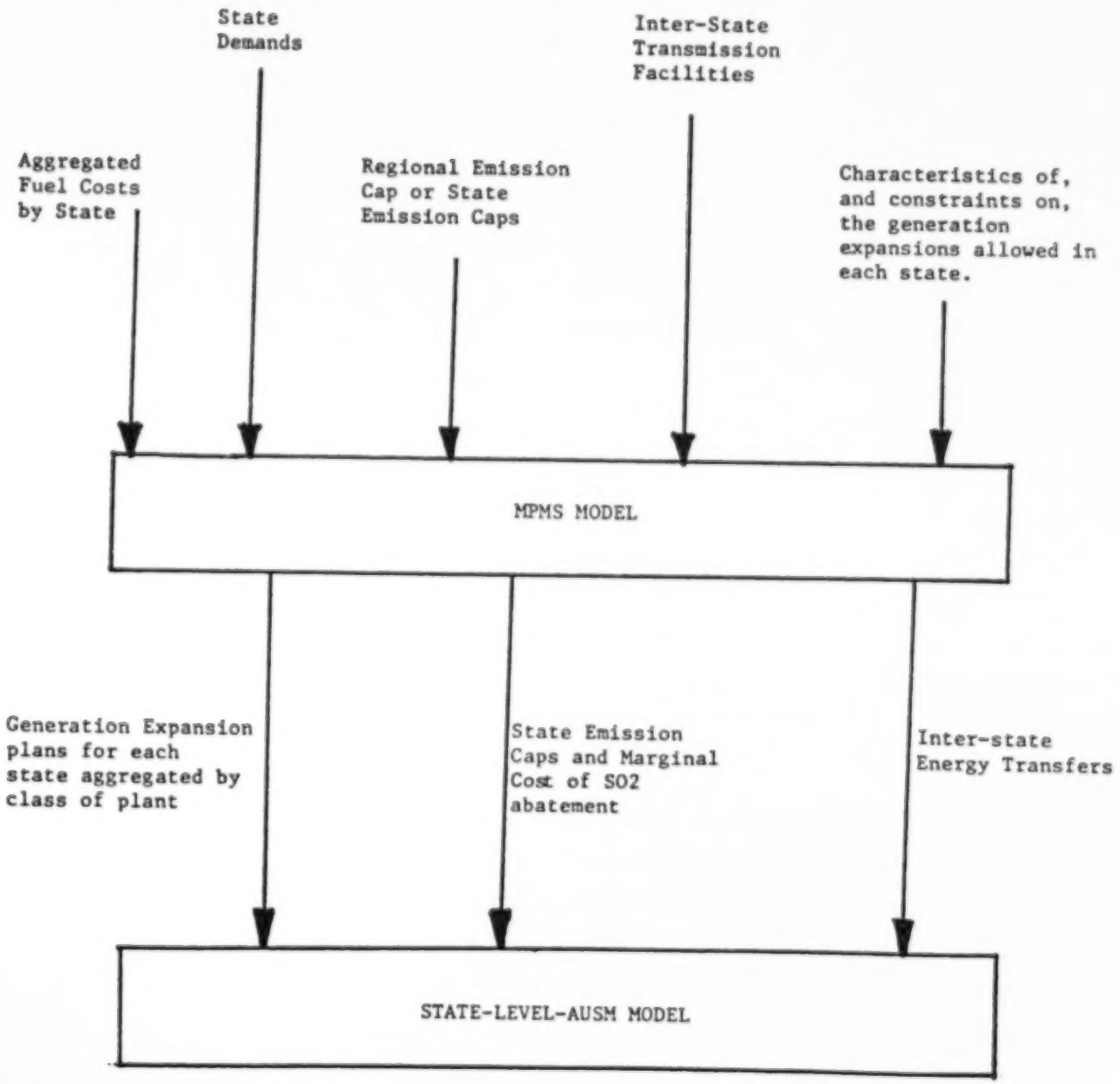
The strongest connections between the MPMS model and the state-level-AUSM are shown in figure 1-1.

1.3. Methodology.

The multi-period multi-state (MPMS) problem is formulated as a linear programming model using aggregated, rather than the individual, plant and fuel categories. Instead of directly solving this problem as a single linear programming problem, which is potentially unmanageable, the problem is handled instead by a heuristic decomposition technique.

The method used to solve the multi-period multi-state model is to solve a sequence of backward-looking single-period multi-state problems which yield the desired information on state aggregated additions, inter-state flows, state emissions, and fuel consumptions.

Figure 1-1: The information flows and "strong" couplings between the MPMS model and the State-Level-AUSM.


State Demands
Inter-State Transmission Facilities
Aggregated Fuel Costs by State
Regional Emission Cap or State Emission Caps
Characteristics of, and constraints on, the generation expansions allowed in each state.
MPMS MODEL
Generation Expansion plans for each state aggregated by class of plant
State Emission Caps and Marginal Cost of SO2 abatement
Inter-state Energy Transfers
STATE-LEVEL-AUSM MODEL

* Up to 10 classes of plants are allowed (e.g. 5 coal classes and 5 non-coal classes)

SECTION 2

AN OVERVIEW OF THE MULTI-PERIOD, MULTI-STATE MODULE

2.1. Model Environment

The MPMS model tackles the following problem.

Given:

1. A region containing a number of states with one load and generation center (node) for each state.
2. A Time Horizon divided into periods.
3. The demand in each state for each period, given in the form of a squared duration curve.
4. The cost, availability, heating value and pollution content of a limited number* of representative fuels for each state and each period.
5. The costs and other characteristics of a limited number of classes of generating plants in each state and for each period.
6. The costs, efficiencies and other characteristics of a limited number of pollution control technologies for each state and each period.
7. The transmission lines between state nodes, their capacities and losses for each period.
8. The state emission caps and/or the regional emission caps.

Find:

1. The inter-state energy transfers in each sub-period.
2. The type, timing, size and location (by state) of generation expansions. Also, the amounts of pollution control retrofits.
3. State emission caps, if they were not specified in the input. Also, the marginal cost of SO2 abatement.
4. The amounts of the fuels burned in each period and each state.

This problem is formulated as a Linear Programming Problem, and is to be solved using a decomposition technique. A few words about the decomposition are appropriate here. There are several standard ways to decompose an LP problem [1-5]. Unfortunately, the general decomposition methods offer little in the way of improved running time or diminished storage requirements over the various sparse-matrix implementations of the Simplex algorithm. Instead of using one of these, knowledge of the

*Three coal types, two oil type, and one of each other

problem and a "means-ends" approach has been used to obtain a new decomposition method.

Using the bounds on the capital variables as controls, the decomposition, for each period,

1. allocates the total generation plant expansions for the region to the individual states;
2. allocates the energy generation for the region to the individual states (i.e. determines inter-state energy transfers);
3. and subdivides the regions emission caps among the individual states.

In making these allocations and subdivisions, the algorithm takes the inter-state transmission losses and capacities into account.

Theoretically, it may be necessary to reiterate over the periods until the solutions converge, however, in general no more than one or two iterations ought to be required for a satisfactory solution.

SECTION 3

PROGRAM DESIGN

The MPMS package consists of the main group of programs and a series of auxiliary programs. The functions of the auxiliary programs are to aid in the interfacing of MPMS to the main AUSM databases. The following sections will detail the functions of the four preparatory programs and the MPMS program,

3.1. Preparatory Programs

The preparatory programs take data from the main AUSM database and put it into a form that MPMS can use directly. This is done by selecting the data for the appropriate states and using interpolation and aggregation to get the desired output. The four preparatory programs are MPMSA1 (fuel program), MPMSA2 (plant aggregation program), MPMSA3 (demand program), and MPMSA4 (transmission program).

3.1.1. MPMSA1

The purpose of the MPMSA1, the fuel program, is to generate an information file of the fuels available to the plants in the region for each period of interest. Since MPMSA1 reads from files with information on the fuels for only certain periods, a simple linear interpolation is done to derive information for intermediate periods.

INPUTS:

- Scenario File - REGSCN.DAT
- Coal File - MPMSP1.DAT
- Alternate Fuel File - MPMSP2.DAT

OUTPUTS:

- Regional Fuel File - MPMSI1.DAT.

3.1.2. MPMSA2

The purpose of MPMSA2, the regional aggregation program, is to pull out from the unit inventory files the information describing plants from a collection of states which have been grouped into a Region. The information aggregated, for each state by fuel type and, for coal plants, size and age to yield ten categories. Appropriate information characterizing each category is computed for output for each period.

INPUTS:

- Scenario File - REGSCN.DAT
- Unit Inventory File - MPMSP3.DAT
- Announced Unit Inventory File - MPMSP4.DAT

OUTPUTS:

- Regional Aggregated Inventory - MPMSI2.DAT

3.1.3. MPMSA3

The purpose of MPMSA3, the demand program, is to generate the load curves for the various states and periods in the study. The user may wish to bypass this program and generate his own MPMSI3.DAT file directly.

INPUTS:

- Scenario File - REGSCN.DAT
- National Demand Files - MPMSP5.DAT

OUTPUTS:

- Regional Demand File - MPMSI3.DAT

3.1.4. Transmission Program

The purpose of MPMSA4, the transmission program, is to generate a table showing the efficiency rate for transferring from one state to another in the region and costs for line rental.

INPUTS:

- Scenario File
- Distance Data File - MPMSP6.DAT

OUTPUTS:

- Regional Transmission File - MPMSI6.DAT

3.2. MPMS

MPMS is the main set of programs. INPUTS:

- Regional Fuel File - MPMSI1.DAT
- Regional Aggregated Inventory File - MPMSI2.DAT
- Regional Demand File - MPMSI3.DAT
- Regional Transmission File - MPMSI4.DATRTRANS.DAT
- New Plant Characteristics - NTPLNT.DAT
- Scenario File - REGSCN.DAT

OUTPUT:

- Operational Output - E9
- —

SECTION 4

DATA BASE DESIGN

There are three type of files used or generated by MPMS. The first type is the preliminary file. There are six such files, each of which is used by an preparatory program to generate an intermediate file. The second type is the intermediate file. There are six such files, four of which are generated by the preparatory programs, one of which is from the database, and one of which is provided by the user. The final type is the output, which consists of three files.

4.1. Regional Scenario File

Besides the scenarios or options that are available to the EPOS model (such as scheduled capacity addition and fuel restrictions), the main option allowed for in the national model is regional and/or state constraints on emissions and fuels. That is, any state may or may not have such a constraint and the region may or may not have such a constraint. The scenario parameters are contained in the file REGSCN.

The purpose of the scenario file is to define the states involved in the region of study, the starting year and duration of the study, and other parameters.

The format of the file is as follows

A10	Title of Run
I2	Number of States in Region
I3,1x,A15	State Code, Name of State (one record for each state in region)
.	
.	
Blank Line	
I5,I3	Starting Year, Number of Periods
3(5I2/)	Number of Years in Each Period
I4	Starting Year for New Coal Category
Blank Line	
I2	Grouping Option 0-By State, 1-By Region, 2-Both
I2	Number of Segments in LDC
5(F7.1)	Number Hours in Each Segment of LDC
Blank Line	
4F6.3	Discount Factor, Annual Demand Increase, Annual Capital and Variable Cost Increase
3(5e8.1)	Tons/Year SO2 limit

The Scenario File is provided by the user and gives the parameters needed to describe the run. Following is a sample scenario file.

```
ECAR                Title of the Run, (A10).
100001              Run number, (I6).
5                   Number of States in Region, (I3).
```

```
18 INDIANA          List of State ID codes and State names, (I3,1X,A15).
21 KENTUCKY
26 MICHIGAN
39 OHIO
54 W. VIRGINIA

1985 10             Starting Year of run, Number of Periods in Run, (I5,I3).
1 1 1 1 1           Number of Years in each Period, 3(5I2).
2 2 3 3 5

1980                Starting Year for 'NEW COAL', (I4).

0                   Grouping Option, (I1).  (1 for Regional Aggregation,
                     0 for State Aggregation, 2 for Both.)

3                   Number of Segments in LDC.
 876.6 4383.0 3506.4  Number of Hours in each Segment OF LDC, (5F7.1).

0.909 0.020 0.000 0.000   Discount Factor, Annual Dem Increase
                          Annual Capital, Variable Cost Increase, (4F6.3).
```

4.2. Preliminary Files

There are six preliminary files in the database

4.2.1. MPMSP1

MPMSP1 is the alternate fuel file which consists of two sections. The first section has five records, one for each of the alternate fuel types. Each record contains:

Format	Columns	Contents
I2	1-2	Fuel code
I2	3-4	Number of years
I5	5-9	First year for fuel data
I5	10-14	Second year for fuel data
I5	15-19	Third year... etc.

The second section consists of five records for each state, with each record containing the fuel characteristics (which are invariant over time) plus the cost data for each of the years given in the corresponding record in section one.

Format	Columns	Contents
I2	1-2	State FIPS code
I2	3-4	Fuel code
I6	5-10	HHV
F5.2	11-15	%SO2
F5.2	16-20	%Ash
F4.0	21-24	cents/MMBTU for first year
F4.0	25-29	cents/MMBTU for second year

4.2.2. MPMSP2

MPMSP2 is the coal file, which consist of three sections. The first section consists of a single record in I3 format giving the number of lines in the second record, which describes the data in the third record. The third record contains the coal data for the various states and years.

Format	Columns	Contents
I4	1-4	Year
I3	4-7	State FIPS code
I3	8-10	SO2 category
I3	11-13	HHV category
E10.4	14-23	Price (cents/MMBT)
I2	24-25	Supply region
E10.4	26-35	HHV
E10.4	36-45	%Ash content

4.2.3. MPMSP3

MPMSP3, the unit inventory file, consists of four sections. The first section consists of a single record in I3 format which gives the number of records in the second section, which is a verbal description of the data. The third section consists of five records giving the number of entries for each of the states. The fourth section consists of the data describing the units. Each unit is represented by six records. The information used by MPMS is the following:

RECORD	COLUMNS	FORMAT	CONTENTS
1	1 - 5	I5	PLANT SEQUENCE NUMBER
	15 - 20	F6.2	MULTIPLIER (SHARE OWNED)
2	8 - 13	F6.0	HEAT RATE
	19 - 23	F5.0	CURRENT CAPACITY (MW NET PENALTIES)
	24 - 26	F3.2	DESIGN CAPACITY FACTOR (FRACTION)
	30 - 32	F3.2	ESTIMATED AVAILABILITY (FRACTION)
	44 - 47	F4.1	NONFUEL VARIABLE O&M COSTS (MILS/KWHR)
	51 - 54	I4	YEAR ON-LINE
	55 - 58	I4	RETIREMENT YEAR
3	4 - 5	I2	PRIM FUEL CODE

4.2.4. MPMSP4

MPMSP4, the announced unit inventory file, is similar to MPMSP3. The main difference is that each unit in section 4 is described by two records instead of six. The information MPMS uses from this file is:

RECORD	COLUMNS	FORMAT	CONTENTS

1	1 - 5	I5	PLANT SEQUENCE NUMBER
	15 - 20	F6.2	MULTIPLIER (SHARE OWNED)
2	8 - 13	F6.0	HEAT RATE
	19 - 23	F5.0	CURRENT CAPACITY (MW NET PENALTIES)
	24 - 26	F3.2	DESIGN CAPACITY FACTOR (FRACTION)
	30 - 32	F3.2	ESTIMATED AVAILABILITY (FRACTION)
	44 - 47	F4.1	NONFUEL VARIABLE O&M COSTS (MILS/KWHR)
	51 - 54	I4	YEAR ON-LINE
	55 - 58	I4	RETIREMENT YEAR

4.2.5. MPMSP5

MPMSP5 is the demand file and consist of two sections. The first section is a single record giving the five years for which demand estimates are provided. The format of this record is 5I5. This record is followed by a blank line. The second section consists of demand data for the state in ascending FIPS code order. Each state entry has three records:

Record 1

Format	Columns	Contents
I3	1-3	State FIPS code

Record 2

Format	Columns	Contents
F15.6	1-15	Load factor for first year
F15.6	16-30	Load factor for second year

Record 3

Format	Columns	Contents
F15.0	1-15	Sales (GWHr) first year

4.2.6. MPMSP6

MPMSP6, the distance data file, consists of two sections. The first section consisting of a single recording format 2F5.3, gives the annualized cost of transmission lines (cents/KWH for 100 miles) for a 345 and 700 KW lines, respectively. The second section gives the distances between states for the various regions.

Record 1

Format	Columns	Contents
I3	1-3	Region number
I3	4-6	Number of states in region

Record I+1

Format	Columns	Contents
I3	1-3	FIPS code of Ith state in region
I3	4-6	FIPS code of first non-I state in region
F6.0	7-12	Distance between Ith state and state in columns 4-6
I3	13-15	FIPS code of second non-I state in region

F6.0	7-12	Distance between Ith state and state in columns 13-15
Etc.		

4.3. Intermediate Files

4.3.1. MPMSI1

MPMSI1, the interpolated fuel file, consists of four sections. The first section, consisting of a single record in I3 format, gives the number of records in the second section, which is a verbal description of the file. The third section, consisting of a single record in I3 format, gives the number of different fuels for each time period (this number usually is the number of states in the region times 9). The fourth section gives the cost and characteristics for each fuel by time period and state, which consist of a single record. The records are grouped first by state, and then by fuel (that is, all the records for a single state are together).

Format	Columns	Contents
I3	1-3	State FIPS code
I3	4-6	Fuel code
I5	7-11	Beginning year of period
E10.4	12-21	Fuel cost cents/MMBTU
E10.4	22-31	HHV
E10.4	32-41	%SO2
E10.4	42-51	%Ash
A4	53-56	Fuel Name

4.3.2. MPMSI2

MPMSI3, the aggregated plant file, consists of three sections. The first section, consisting of a single record in I2 format, gives the number of records in the second section, which is a verbal description of the file. The third section consists of one block for each state in the region, with each block containing 2 records for the state, and 9 records for each of the 10 plant category descriptions (92 records total per block)

Blank Line	
I2	State FIPS code
Blank Line	
A10	Plant category name
6x,10F7.2	O&M costs
6x,10F7.3	Availability
6x,10F7.3	Capacity factor
6x,10F7.0	Generating capacity
6x,10F7.0	Average plant size
6x,10F7.0	Scrubber capacity
Blank Line	
A10	Plant category name
6x,10F7.2	O&M costs

4.3.3. MPMSI3

MPMSI3, the demand file, consists of three sections. The first section, consisting of a single record in I4 format, gives the number of records in the second section, which is a verbal description of the file. The third section consists of one record for each state and period combination.

Format	Columns	Contents
I3	1-3	FIPS code of state
I5	4-8	Beginning year of period
F10.0	9-18	Height of 1st segment of load curve (MW)
F10.0	19-28	Height of 2nd segment of load curve (MW)
F10.0	29-38	etc.

4.3.4. MPMSI4

MPMSI4, the transmission file, consists of one section, which is a table of line efficiencies and line rental costs. There are two records for each state.

Record 1

Format	Columns	Contents
I3	1-3	FIPS state code
F10.6	4-13	Efficiency of line to 1st state in region
F10.6	14-23	Efficiency of line to 2nd state in region
F10.6	24-33	etc.

Record 2

Format	Columns	Contents
3x	1-3	Blank
F10.6	4-13	Cost/MWHr line rental to 1st state in region
F10.6	14-23	Cost/MWHr line rental to 2nd state in region
F10.6	24-33	etc.

4.3.5. NTPLT

NTPLT, the new plant characteristics file, consists of 4 records, one for each new category.

Format	Columns	Contents
I2	1-2	Prime mover
E12.4	3-12	Availability
E12.4	13-22	Capacity factor
E12.4	23-32	Heat rate
I2	33-34	Construction period
I2	35-36	Expected lifetime
E12.4	37-46	Plant size
E12.4	47-56	O&M costs
E12.4	57-66	Capital cost of construction $/KW

4.4. Report Files

MPMS generates 4 report files. The first (FOR11) is a trace file written by the XMP library in the course of solving the linear programming problems. The second is a report file used by the state AUSM (REGRPT). The third is a wordy report (REGOUT), and the fourth is a trace file from MPMS (REG1). REGOUT gives basically the same information as REGRPT, but in more readable form. REG1, depending on the trace level chosen, gives more detailed information for the solution (such as power transfers between states instead of net transfers).

REGRPT consists of three sections, the first of which is a textual description of the simulation. The first record of this section gives the number of the remaining records in that section. The second section consists of 16 records describing the simulation.

Record	Format	Contents
1	I2	Number of states
2	10(I3)	State FIPS codes
3	I2	Number of time periods
4	I4	Base year
5	15(I5)	End years of each time period
6	I2	Number of plant categories
7	5f6.0	Descriptors for plant category 1
		a. fuel type
		b. size lower bound
		c. size upper bound
		d. year on-line lower bound
		e. year on-line upper bound
8	5f6.0	Descriptors for plant category 2
	.	
	.	
16	5f6.0	Descriptors for plant category 10

The third section consists of subsections for each of the state.

State Record	Format	Contents
1	I2	State FIPS code
2	5F4.2	Mix of plants built during simulation (fraction)
		a. coal
		b. nuclear
		c. peaking
		d. oil
		e. other
3	F10.2	General information for time period 1
		a. Transfers of power
		b. Revenues from power transfers
		c. SO2 emission cap
		d. Dual variable of SO2 cap
		e. Ratio of available capacity to peak output
		f. Ratio of annual generation capacity to annual output

4	10F5.3	Capacity factors for each plant category
5	5F10.2	General information for time period 2
6	10F5.3	Capacity factors for each plant category

etc.

SECTION 5

REFERENCES

1. R. . Marsten, "The Dessign of the XMP Linear Programming Library", *ACM Transactions on Mathematical Software*, Vol. 7, No. 4, pp. 481-497, Dec. 1981.

Appendix A
Fortran Coding Restrictions.

The AUSM has been coded in 1966 ANSI FORTRAN. Any FORTRAN library routine included with the model also must conform to the standard, and source code must be provided for all such routines.

The AUSM is to be integrated and tested on the CYBER 175 at UIUC, manufactured by the Control Data Corporation (CDC), and transferred to the EPA IBM computer. This appendix list. some restrictions to the FORTRAN language that will assure greater portability between the IBM and CDC machines. These restrictions apply to all modules developed for the AUSM and associated library routines.

Arrays

The maximum number of array dimensions is seven.

A reference to an individual array element must specify a value for each dimension in the array.

NOT acceptable:

```
DIMENSION A(5,5,5)
B = A(3,2)
```

NOT acceptable:

```
DO 10 I = 1, 125
A(I) = 0
10 CONTINUE
```

Assignments

Multiple assignment statements (e.g., I=J=0) are not permitted.

Characters

A single quote is the preferred character string delimiter.

Type CHARACTER may not be used.

A maximum of four characters may be stored in a single word.

Comments

Comment lines must begin with a C in column 1.

Comment lines may not follow an END statement, nor may they occur before a PROGRAM, SUBROUTINE, FUNCTION, or BLOCK DATA statement.

Constants

Octal and hexadecimal constants may *not* be used.

Continuations

Continuation lines begin with a nonblank character in Column 6. Columns 1 through 5 are blank.

A maximum of 19 continuation lines is allowed.

Continuation lines may not be interleaved with comments or blank lines.

DATA Statements

DATA statements follow all type specifications and appear before any executable statements.

DO Loops

DO loops must be of the following form:

```
DO stmt index = N1, N2 [, N3]
.
.
.
stmt CONTINUE
```

where 'stmt' is a statement label and N1, N2, and N3 are positive integers or integer variables. Array elements and expressions may not be used as DO loop indices.

It is not assumed that a DO loop is either skipped or executed one time if N2 is less than or equal to N1. This condition should be tested prior to entering a loop.

The loop index is assumed to be undefined upon completion of a loop.

Exponentiation

Parentheses should be used to indicate the order in which exponential expressions are evaluated:

CDC FORTRAN: A**B**C ---> (A**B)**C

IBM FORTRAN: A**B**C ---> A**(B**C)

Expressions

Expressions may not be used in I/O lists.

NOT ACCEPTABLE: Print 10, A, B, C*100

Expressions may not be used as indices in DO loops.

NOT ACCEPTABLE: DO 100 I = 1, N-2

GO TO (Assigned)

The assigned GO TO is not permitted.

GO TO (Computed)

The ranges of a computed GO TO index *must* be checked. For example:

```
IF( I .LT. 1  .OR.  I .GT. 4 ) GO TO 5
GO TO( 100, 200, 300, 400 ), I
```

Initialization of Variables

All variables must be properly initialized within the program. It is not assumed that core is automatically initialized to zero.

Data appearing in labeled COMMON blocks must be initialized in a BLOCK DATA subprogram.

I/O

No function references or expressions may appear in an I/O list.

Conventional unit numbers are used for standard input (unit 5) and standard output (unit 6).

Multiple Statements

No more than one statement may appear on a single line.

Names of Variables

Variable names consist of one to six letters or digits beginning with a letter. Blanks may not appear in variable names.

Mnemonic names are used when possible.

Implicit variable typing is preferred; variable names beginning with the letters I, J, K, L, M, and N are of type INTEGER; all others are of type REAL.

Operators (Logical)

The only valid logical operators, listed by precedence, are:

.NOT.
.AND.
.OR.

Operators (Relational)

The only valid relational operators are:

.LT.
.LE.
.EQ.
.NE.
.GE.
.GT.

PAUSE

The PAUSE statement requires user intervention; it is not used.

STOP

The STOP statement must be of the form:

STOP [n]

where n is a string of 1 to 5 decimal digits.

SUBROUTINE

A subroutine may have only one entry point and only one exit point. ENTRY statements or RETURN lists are not used.

Word Length Dependency

Any features that are dependent on word length may not be used. This includes ENCODE DECODE, and masking expressions.

A maximum of four characters may be stored in a single word.